Turning point

CRP Azipod® gives a boost to marine propulsion efficiency

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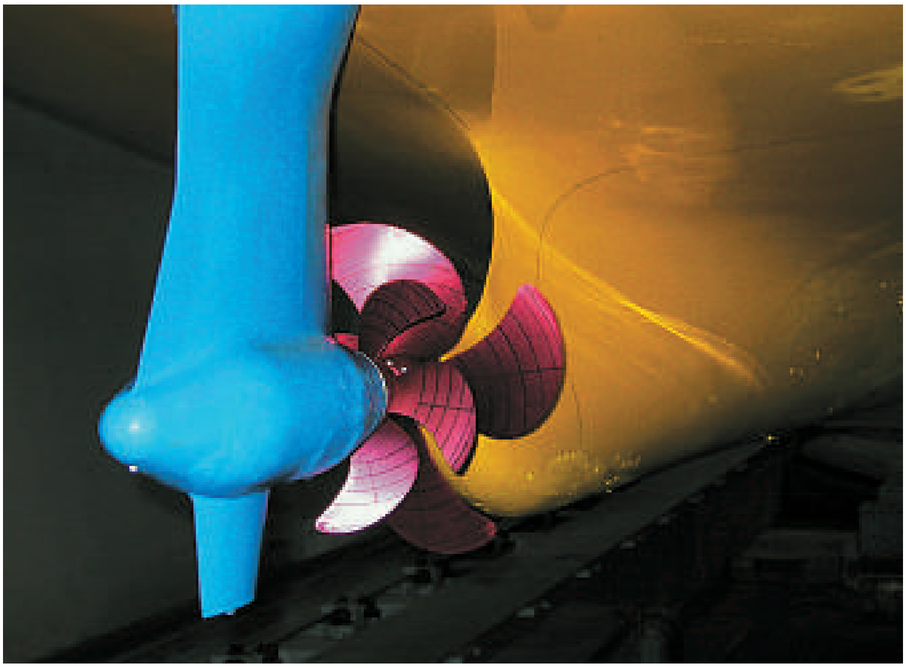


Almost as old as the invention of the screw propeller itself, the concept of contra-rotating propellers has been held back in the past by its association with complex shafting and gearing. However, technology is available with which this costly hindrance can be overcome. CRP Azipod, opens up a new era by offering ship operators a drive system with contra-rotating propellers that makes full use of the experience base built up by ABB with its proven Azipod electric propulsion unit.

The contra-rotating propeller concept that lies at the heart of CRP Azipod® combines two separate marine propulsion systems – a conventionally driven main propeller and a downstream propeller aligned on the same axis and rotating in the opposite direction. The forward, main propeller is coupled directly or via gearing to the main engine(s), while the in-line aft propeller is driven by an electric motor inside a submerged pod that can be steered through 360 degrees.

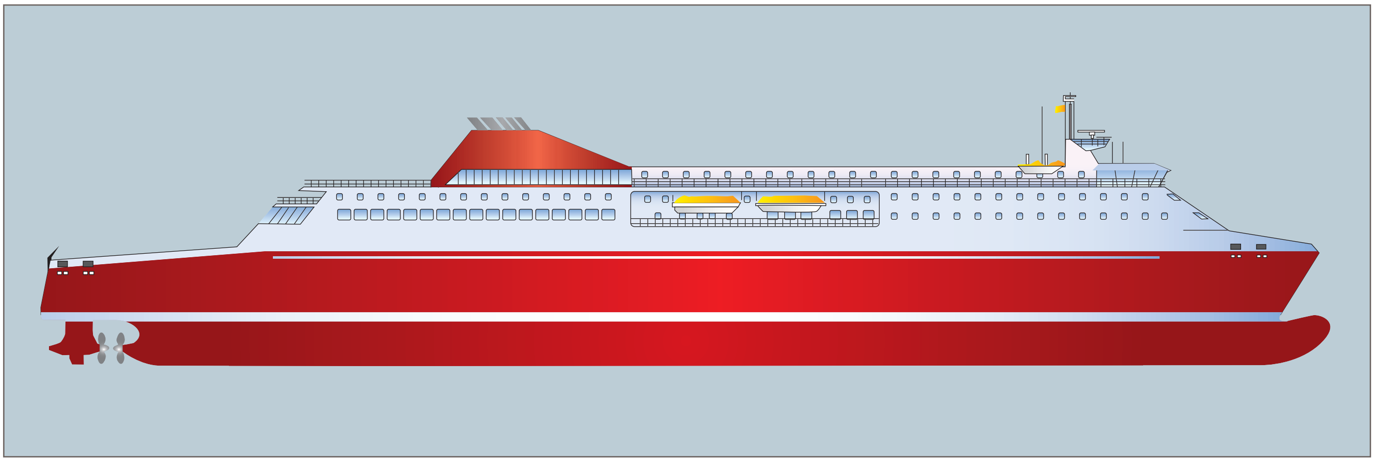
CRP Azipod avoids the gearing, bearing and sealing problems associated with complex CRP shaft systems having an inner shaft rotating in a second, hollow outer shaft. Besides improving the reliability of the system as a whole, eliminating these problems also gives designers more freedom with the engine room layout. Added to these are the advantages common to all pod drives, like excellent dynamic performance and maneuvering characteristics, including the ability to turn through 180 degrees for an increase in backing thrust.

A further advantage is that the Azipod unit can be fitted in place of a conventional ship's rudder, allowing the single-screw hull lines, with the advantages of low resistance and high efficiency, to be retained.

Why CRP?

A contra-rotating propulsion system is better than conventional propulsion for several reasons. For example, the main propeller's forward rotational velocity component is recovered; also, since the power is divided between two propellers, the individual propeller load is reduced, allowing the propellers to be built with smaller diameters. Smaller propeller diameters have another important advantage: The clearance between the propeller tip and hull is enlarged, reducing noise transmission as well as vibration levels on the ship's hull. At the same time, the Azipod hull itself acts as a rudder behind both propellers, straightening

1 Fast Ropax vessel with CRP Azipod propulsion



the flow downstream and adding some extra thrust. Results from tests in model basins indicate that this system is a serious alternative for ships whose owners need to increase the propulsive efficiency or reduce vibration and noise levels.

What kind of ships would benefit?

The improvement in propulsive efficiency obtained with CRP Azipod, compared with that of a conventional single- or twin-screw vessel, depends on the propeller load and speed of the ship in question.

CRP Azipod combines a conventionally driven main propeller with a downstream contra-rotating propeller aligned on the same axis.

In the case of a single-screw vessel with propeller designed to operate in both smooth and wake fields, and assuming moderate loading, the gain in total propulsive efficiency with CRP will be small, even marginal. This is because present propeller designs are optimized and already exhibit very high efficiency. For such ships, the benefits of CRP lie in other areas altogether – for example in maneuvering, propulsion redundancy, smaller engine rooms, or reduced noise and vibration.

The advantages of CRP Azipod really come to the fore with ships having a conventional propulsion system that exerts a very high load on the propeller at high design speed or where restrictions are imposed on the size of propeller that can be fitted. Ships this could apply to include fast RoPax vessels 1, ultra-large container vessels and LNG carriers. Due to the different ways in which CRP Azipod can be used, its suitability and the benefits it would bring have to be considered from case to case.

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Tests indicate much better performance

Model tests carried out with several different types of ship have produced very promising results. In one recent study of an ultra-large container vessel, carried out in a model basin, three different propulsion systems – single-screw, twin-skeg[1] and CRP Azipod – were compared to determine the real difference in performance. All the propellers and hull forms were optimized, and every effort was made to ensure accurate and reliable results.

The tests showed that the vessel with CRP Azipod performed 9% better than the twin-skeg ship and 5% better than the single-screw vessel 2. These figures take into account the mechanical and electrical losses in each case. In fact, the

[1] A skeg is a fin-type device located near the stern of the ship on the hull, and is fitted to help keep the ship tracking straight.

performance difference is even greater (by 2%) when the power delivered at the propeller is compared.

The performance results make out a clear case for CRP Azipod. Smaller propulsion machinery and reduced fuel consumption are the two main advantages that stem from the gain in efficiency.

The main reason for the efficiency being better with CRP Azipod than with the single-screw vessel is the reduced propeller load. In the comparison with the twin-skeg vessel, it was better because of the ship's hull resistance being lower and because of the CRP effect itself. Obviously, the propeller load can also be reduced on the twin-skeg vessel by dividing it between two propellers.

ABB also initiated a fast RoPax research project to study the CRP Azipod concept. This involved a large series of model propulsion tests at Marintek, a marine technology center based in Norway, in which different failure scenarios were investigated, eg operation with one propulsion unit working (either the main propeller or the Azipod unit) and the other out of action. The tests were very successful and valuable information was collected for future project design and development work.

2 Performance predictions for three different propulsion systems

The predictions, based on model tests, are for an ultra-large container vessel with single-screw (SS), twin-skeg (TS) and CRP Azipod propulsion.

Based on our experience to date, the efficiency gain with CRP Azipod could be as high as 15%, but will depend on the type of ship and its propulsion configuration.

Designing for an optimum power split

The design process is characterized by several boundary constraints that need to be defined already during the project offer phase. The speed and diameter of the main propeller, for example, are usually more or less fixed, as they are determined by the main engine rpm and the clearance to the hull. Also fixed, for a given power rating, are the pod unit size and speed, but here the designer has options as he can choose the size and type of electric motor to be used. Together, these factors define the optimum power ratio. While a 50:50 power split is always the target, the optimum ratio for a particular ship is obtained iteratively in a process in

which the choice of main engine rating and pod size plays a key role. In any case, the pod size will be chosen based on a consideration of both cost and hydrodynamic efficiency.

Power ratio

Normally, the pod unit provides between 30% and 50% of the total propulsive power. However, to maximize the efficiency gain the propellers need to provide equal amounts of power, and the achievable gain decreases when there is any deviation from this ideal situation. ABB considers a power ratio of not less than 30:70 to be acceptable for good hydrodynamic efficiencies. When vessels have to be upgraded for a new route that requires more speed, so-called booster power will be needed, and in such cases the power ratio can drop below 30% as it is speed and maneuvering capability which are needed here, not optimum propulsive efficiency. A look at the torque and thrust ratios shows that they also closely reflect the propeller power ratio.

Propeller diameters

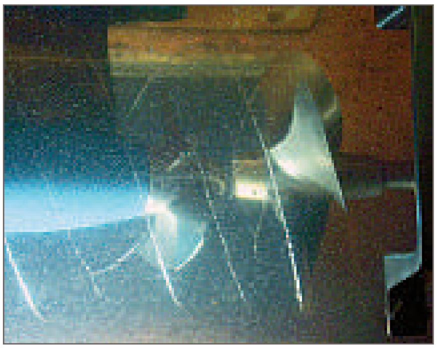
When the propulsive power is distributed equally between the propellers the optimum diameter of the aft propeller is 85% to 92% that of the forward propeller. Thus, if the power distribution changes careful consideration has to be given to the aft-propeller diameter. For example, comparative calculations have to be carried out to determine what its optimum diameter would be. If we assume a 30% to 70% power distribution, the diameter of the aft propeller can be as little as 70% to 80% of the forward-propeller diameter.

The Azipod propeller diameter should be selected so that, in normal operation, the propeller disk remains within the main propeller slipstream. This will ensure that the blades of the Azipod propeller do not collide with the main-propeller tip vortex, which would cause cavitation and vibration problems.

Cavitation

The cavitation characteristics of the two propellers are very important, not only because of the harmful effect they can

3 Cavitation tunnel set-up for the CRP Azipod system



have on the propeller blades but also because of how they can influence the pressure pulse level on the hull and increase vibrations in the shaft line.

The design of the Azipod propeller was a particular challenge as it operates in the highly non-homogeneous slipstream created by the main propeller. A key design criterion, perhaps even the most important one, for both propellers and the Azipod strut is the fact that no harmful cavitation occurs that could cause erosion between the steering angles of ± 7.5 degrees. This zone covers the autopilot steering angle range for a ship traveling at its normal service speed.

The forward propeller is not unlike the propeller in a conventional single-screw configuration, and is therefore relatively easy to design. When it has good cavitation characteristics – involving the tip vortex, hub vortex and sheet cavitation – the design of the aft propeller is much easier. The propellers should be designed together, not separately, as they work very close to each other and affect each other's operation. Given that the Azipod propeller works completely within the slipstream of the main propeller, the latter's downstream wake needs to be as close to ideal as possible to make it easier to design the aft propeller. 3 shows the cavitation tunnel set-up used in the tests, with the main propeller tip vortex visible on the left of the figure. The main-propeller hub cavitation tends to present the most difficult problem. When the Azipod unit is steered – by shifting the Azipod propeller plane to either side – the hub vortex produced by the main propeller may collide with the blade roots of the aft propeller. This can lead to cavitation on the aft-propeller blades, possibly causing harmful erosion. The main propeller's hub has to be designed carefully with a view to preventing this phenomenon.

The strut of the Azipod housing lies in a mixed flow field, the upper part being in the hull boundary layer and ship's wake and the lower part in the combined – and highly non-homogeneous – wake of the two propellers. The strut profile needs to be designed in a way that causes no cavitation at all, or at the least so that no harmful cavitation can occur in normal operating conditions.

CRP Azipod is the latest example of ABB innovation in marine propulsion, and extends the applicability of the Azipod concept into a new area.

Pressure pulse level and vibration

A problem today is that the shipping industry wants faster ships – ie, ships with more propulsive power – but does not expect the extra speed to have to be paid for with higher vibration and noise levels on board. In fact, for some types of ships the vibration and noise levels are actually expected to be lower.

As already mentioned, the CRP system allows a reduction in propeller diameter and an increase in the distance between propeller tip and hull, so this requirement can be met. In addition, splitting the power between the forward and aft propellers can also significantly reduce the vibration excitation levels on the ship's hull.

Normally, the propellers used in a CRP Azipod system have different numbers of blades, so they create different pressure amplitudes at different frequencies. This must also be taken into account when designing the ship's main structures.

Another design consideration is that the steel pod unit and shaft line of the Azipod have to withstand the loads and vibration caused by steering and by the main propeller's operation. Studies have shown that no problems are to be expected.

A system with genuine potential

CRP Azipod is the latest example of ABB innovation in marine propulsion and extends the applicability of the Azipod concept into a new area. The model tests that have been carried out show clearly that this system is a serious alternative for vessels designed for high power and/or high speed. The main benefits of CRP Azipod lie in the efficiency gain, which can be as high as 15%, and the considerable reduction in hull vibration that is possible.

To maintain its position as technology leader, ABB is currently collaborating with partners, ship operators and shipyards on a variety of projects aimed at developing more efficient and sustainable solutions for marine customers.

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